Water quality transformations in distribution systems

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Contents

1 Introduction

Drinking water utilities face numerous difficult challenges to fulfill their primary objective of providing potable drinking water of adequate quality and quantity. The viability of drinking water systems is critical to the protection of public health and the conservation of natural resources (AWWA, 1995). Water distribution systems are planned to provide safe and adequate drinking water to the community. The quality of water within the distribution system may undergo substantial changes with respect to location and time. The factors that influence such changes include (Clark and Coyle, 1990):

- Chemical and biological quality of source water
- Efficiency of treatment process
- Integrity of distribution systems and their appurtenances
- Operation and maintenance of distribution network
- Effect of mixing of water from different sources

Effective periodic monitoring of water distribution system is necessary to ensure its functionality and efficacy. Current surveillance mechanisms in many cities are far from satisfactory, as evident from frequent outbreak of waterborne epidemics. The objective of the present work is to quantify the water quality transformations in water supply system of Bharatpur town and suggest water quality surveillance program for the future. The specific objectives of the study are :

- Monitor drinking water quality from source to end user in Bharatpur town
- Identify critical areas with respect to non-compliance in drinking water quality standards
- Assess community perception on drinking water
- Suggest a water quality surveillance mechanism

Existing water supply scheme in Bharatpur

Planning, implementation, maintenance and collection of revenues for water supply scheme in Bharatpur town is under the purview of Public Health Engineering Department (PHED). The modern water supply scheme of the town was designed for a capacity of 10.4 MLD about 25 years back with Bund Baretha reservoir as primary source of water. Reservoir water is brought to Malah water works via 42 kms long, 600 mm diameter Reinforced Cement Concrete (RCC) gravity main. At Malah water works, water is subjected to treatment consisting of sedimentation, flocculation, filtration and post-chlorination processes. However, over a period of time, increase in water demand due to population growth

coupled with the reduction in the carrying capacity of the gravity main due to leakage and scaling, the designed water supply scheme could not meet the water needs of the town. Scarcity of funds and an unplanned approach led the PHED to install many deep bore tube-wells in the town to augment water supply. Four deep tube-wells were dug at the Malah water works to blend the groundwater with treated water and nine deep tube-wells located at village Mandoli pump about 21 kms away from Bharatpur city. The designed capacity of these tube-wells was 1 million litres a day, which has been reduced to 150000 litres a day since only two tube-wells are operational. In addition, approximately 20 tube-wells are installed at various locations in the city for supplying groundwater to the consumers directly through the existing pipelines.

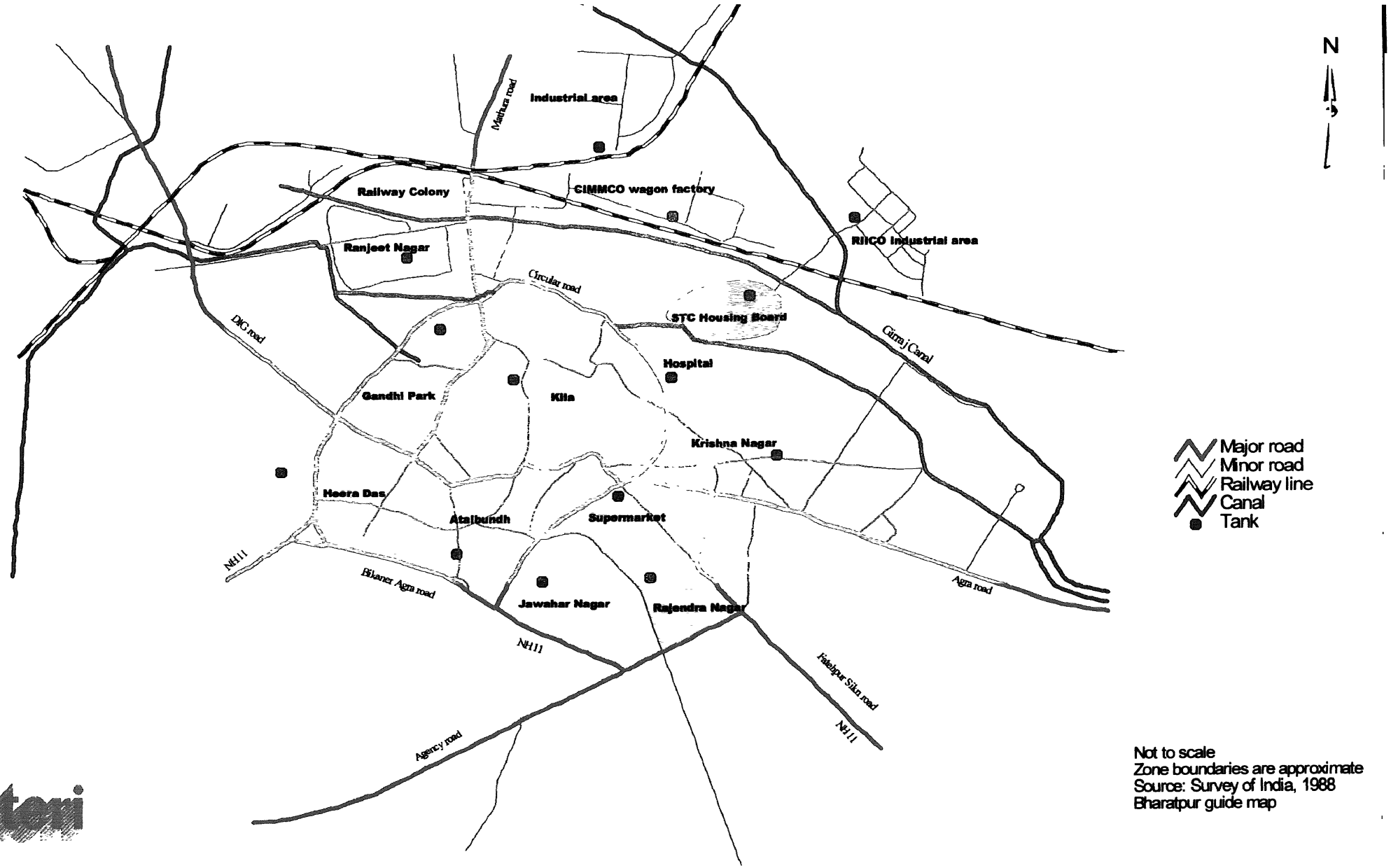
For administrative reasons, the PHED has divided the town into 13 zones and each zone has a separate service reservoir. The water supply zones of Bharatpur are shown in Map 1. The population served by each zone and the water supply (as per the records of PHED) are given in Table 1.

Table 1. Zonewise water supply status in Bharatpur as per PHED records

Zone	Population served (January 1998)	Water supplied as per PHED records KLD (kilolitres/day)
Kila	34 000	2700
Super Market	22 500	1800
Atalbundh	35 000	2700
Gandhi Park	17 500	1400
Ranjeet Nagar	12 600	1260
STC Housing Board	6 300	630
Krishna Nagar	10 800	1080
Rajindra Nagar	11 700	1170
Jawahar Nagar	17 000	1700
Heera Das	23 000	2360
Hospital	-	200
Industnal - I	-	400
Industrial -II	-	500

Source : PHED, Bharatpur

Treated water at the Malah water works is blended with water from four tube-wells at the same site and supplied to the elevated service reservoirs of Krishna Nagar, Kila, Rajinder Nagar, and Super Market zones while the other zones are served with tube-well water only. Even in the zones served by Malah water works, all zones except the Super Market zone, have tube-wells to meet additional the water demand. In fact, groundwater has a major share in meeting water demand of these zones. In Atalbundh and Kila there are 5 and 4 tube wells, respectively, from which the water is pumped and supplied to the residences through pipes directly. The water distribution system is designed as a looped network so that in the case of breakage or a shut down in the pipeline, water



Map 1 Water supply zones of Bharatpur

could be supplied through other zones. However, the water pressure is so low that this seldom happens. An assessment of typical features of water supply in each of the zones is presented below.

Kila Zone

This zone is the largest water supply zone of the town. The service reservoir of this zone has the design capacity of 0.3 million litres which is filled with water from the Malah water works and water from a deep bore tube-well almost in nearly equal proportions. In addition to this, the zone has one open well namely, Barafwala kuan, and 4 deep bore tube-wells within the residential area, which are maintained by PHED and water from these is supplied to the community by pumping into water supply pipelines. Kila zone is further divided into three sectors – Gopalgarh area, Nai mandi area, and area inside the fort.

Gopalgarh

Gopalgarh area has eight colonies: Suraj pole, Sed kamar, Jaghina gate, Janana hospital, Tope muhallah, Baraf factory, Sahayog nagar, and Machi muhallah. Among these, most water scarce colonies are Suraj pole and Tope muhallah. Suraj pole area is at the tail end of Kila zone service reservoir. As a result, it has a very low supply of water (on an average 15 minutes a day). Water supply in Tope muhallah is low because it is at a higher elevation. A 150 mm pipeline in the colony passes through the sewer drain and therefore water is also contaminated. Tope muhallah is also connected from the Hospital zone service reservoir. The five groundwater wells of Kila zone cover the following areas: Baraf factory, Jahgina gate, Janana hospital, inside Suraj pole, and Sed kamar. Water from these wells is not of good quality and people use it only for secondary uses.

Nai mandi

Nai mandi area has 5 colonies: Harijan basti, Railway road, Bajaria, Giriraj and Sarson mandi. Entire Nai mandi area has severe water scarcity. Water is normally supplied during early morning hours at 4 o'clock for about 15 minutes. The drainage system is in close proximity to the water supply pipelines and due to breakage in the pipelines, drains water percolates into the system. The PHED has not been able to trace the damaged portions so far. Harijan Basti pipeline being on the upstream section, subsequent areas are also receiving contaminated water.

Inside kila

Of the 14 areas under this sector the critical areas with respect to water quality are Nadia muhallah, Thandi sadak, Bayania muhallah, Dahiwali gali, and Purohit muhallah. In these areas, the water supply lines are choked and also pass through the drainage lines. The PHED has never attempted to relocate these pipelines.

Super Market Zone

The entire zone is served water from the Malah waterworks. In this zone there is no mixing of groundwater with Malah water works supply. However, there are locations where water is being contaminated due to drain water entering the pipelines at several locations. The zone boundary stretches from Mathura gate to Purana Bijili ghar. Areas served under this zone include: Dhobi basti, Jatav basti, Kohli basti, Gulal kund, Company bagh chowk, outside Mathura gate, Suraj pol outside, Harijan basti and Papdi muhallah, and Suraj pole (mali basti & harijan basti). Suraj pole (Mali basti & Harijan basti) is located at the tail end of the ESR and receives very less water.

Gandhi Park Zone

Gandhi Park service reservoir is supplied through a deep bore tube-well at the same site. However, very recently this well has been closed due to severe deterioration in groundwater quality as the area is very near to Sujan Ganga canal. Presently, the ESR of this zone is served with supply from Heera Das and Kila Zone ESR. However the water availability is not sufficient to meet the water demand of the zone. Also the elevation head of the ESR is very low compared to the elevation of several colonies of this zone resulting in no supply in several areas. Areas served under this zone include: Pai bagh, Wasan darwaja, Namak Katra, Adarsh Nanak, Chandela wali gali, Namak katra-Mali muhallah, Namak katra-Raigarh basti, Namak katra- Munjwana Sardar, Kamla road. Except for Pali bagh, Wasan darwaja and Adarsh Namak colony water pipelines in other colony have leaks at several locations and supply is very less.

Heera Das Zone

This zone has an elevated storage reservoir (ESR) and clear water reservoir (CWR) to cater to water demand. The ESR receives water from a) Tube-well at ESR site itself b) Mandoli water supply scheme c) Malah water works (if the need arises). In addition, 5 tube-wells near Kucha danda, Neem darwaza also contributes to the Heera Das ESR. About half of the total Heera Das ESR capacity is supplied to a clear water reservoir CWR at Anah gate for the main city area supply. The colonies that fall in the Heera Das zone are Korian mohalla, Dhobi basti, Kunda roomram, Kasai wali gali, Pratap Colony, Anah gate Bajaria, Neem

ka gate, Anah gate Harijan basti, Arya samaj road, Aggarwal school, and Kherapati mohalla. The zone has several unauthorised colonies such as Subhash nagar, Idgah colony, Bajrang colony, Near Bhagwan Talkies, Jaswant nagar, Nagla Heera Das, Anahi Chawan, Vijay Nagar, Indira Nagar, Sher Singh Nagar, Tilak Nagar, and Golpura road. The water supply in all the colonies of this zone is for 15 minutes only each in morning and evening. In Heera Das Zone the city area is more problematic in terms of water supply.

Ranjeet Nagar Zone

This is an UIT approved colony of Bharatpur and has a CWR as well as an ESR. Groundwater from a single tube-well boring is the only source of water in this zone. In addition to A, B, C, D and E colonies, the unauthorised colonies receiving low supply of water are Kanjar Basti, Allahdin ka Nagla, Giriraj Colony and Telephone colony. A typical characteristics of this zone is that almost all houses have underground storage tanks of capacity varying from 4,000 litres to 10,000 litres.

Jawahar Nagar Zone

This zone has a UIT housing board colony, which has a total occupancy of about 10 %. The zone is served by water from a tube-well.

Rajindra Nagar Zone

The water source in this zone includes a tube-well and water supply from Malah waterworks. It has a CWR as well as ESR. The CWR has been abandoned now because almost throughout the year a huge dirty water pond surrounds the CWR and this dirty water enters the CWR and contaminates the water into it. At times, however the water in the CWR is supplied to the unauthorised colonies in the zone - Pushp Vatika, Gauri Shankar, Civil Line, and Patpar Mohalla.

Krishna Nagar Zone

The water source in this zone includes a tube-well and water supply from Malah waterworks. The colonies that fall in this zone include: Housing board, Sanjay Nagar, Krishna Nagar, Geeta Colony, Vikas Nagar, Govind Nagar and Kakaji ki Kothi. The zone has a CWR and an ESR. Though the boring is not far from the ESR, water is first pumped into the CWR for mixing with water from Malah waterworks and then finally pumped to the ESR. In most of the houses in Krishna Nagar, people have underground storage tanks.

STC Housing Board Zone

STC Housing Board Colony is an approved UIT colony. In addition, there are two small unapproved colonies in the zone. The zone has its own tube-well and a ESR which is filled once in a day is able to supply water both during morning and

evening.

Hospital Zone

The ESR of this zone, which has a capacity a little less than 0.1 million litre is filled from the supply of Krishna Nagar ESR. The ESR of Hospital zone caters for supply to the Hospital, Agriculture colony behind hospital, Deen Dayal Upadhyaya Colony, Tope Mohalla and Mali Basti on ring road.

RIICO Zone

RIICO is the new industrial zone of Bharatpur. The water from the tube-well in the zone is pumped into an ESR from where it supplied to factories, 33 kV electricity substation colony and unauthorised colonies - Sarvodya Nagar, CIMMCO Labour Colony, and Nagla Tej Singh. Currently, the ESR is in a dilapidated condition and as a result it has not been cleaned for quite some time resulting in highly turbid and saline as compared to boring water which is not turbid and saline.

CIMMCO Zone

The colonies in this zone include the Ekta Vihar colony, Tyonga village, Kare Ka Nagla and a tube-well dug by PHED and two tube-wells dug by CIMMCO management are the only sources of water supply. PHED tube-well is directly pumped into an CWR from where it is supplied into the distribution system.

2 Drinking water quality monitoring

The primary objective of this study is to monitor the drinking water quality from source to end user in Bharatpur town and identify critical areas. Quantification of water quality transformations in distribution system was done by analysing water quality samples from different raw water sources, intermediate distribution nodes (service reservoirs i.e. elevated or clear water) and community taps. Samples at service reservoirs were taken at entry and exit level, so as to ascertain the changes in water quality during its residence in the reservoir. Number of sampling locations from community taps were decided on the basis of the World Health Organization guidelines (WHO, 1995) as given in Table 2. The number of sampling locations thus chosen for each zone during the first phase (August 27 to August 31, 1998) are given in Table 3. Sampling locations at the household level in each zone were decided on the basis of the topography, the expected water pressure and tail end nodes of the tertiary network. Tail end nodes are critical in terms of pressure and residual chlorine concentration. Since the water pressure does not change during the supply timings, therefore, representative samples during high or low pressures are not required.

Table 2 Minimum sampling frequencies for drinking water in the distribution system

Population served	Samples to be taken monthly
Less than 5000	1 sample
5000-100000	1 sample per 5000 population
More than 100000	1 sample per 10000 population, plus 10 additional samples

Source WHO, 1995

Table 3 Sampling locations during first phase of monitoring

Zone	Sampling location	Number of samples
	Malah water treatment plant – Raw water	1
	Malah water treatment plant – Treated water	1
Kila Zone		
	ESR Inlet	1
	ESR Outlet	1
	Household	4
Atalbundh Zone		
	ESR Inlet	1
	ESR Outlet	1
	Household	5
Heera Das Zone		
	ESR Inlet	1
	ESR Outlet	1
	Household	3
Super Market Zone		
	ESR Inlet	1
	ESR Outlet	1
	Household	3
Ranjeet Nagar Zone		
	ESR Inlet	1
	ESR Outlet	1
	Household	2
Krishna Nagar Zone		
	ESR Inlet	1
	ESR Outlet	1
	Household	2
Gandhi Park Zone		
	ESR Inlet	1
	ESR Outlet	1
	Household	3
Rajindra Nagar Zone		
	ESR Inlet	1
	ESR Outlet	1
	Household	2
Jawahar Nagar Zone		
	ESR Inlet	1
	ESR Outlet	1
	Household	3
Tube-wells		
	Heera Das	1
	Ranjeet Nagar	1
	CIMMCO	2
	RIICO	1
	STC Housing Board	1
	Kila	1
	Rajindra Nagar	1

The parameters chosen for analysis are given in Table 4. pH and residual chlorine in the samples were analysed in the field immediately after the sample was collected. Bacteriological samples were collected in separate sterlised flasks and stored in iceboxes until they were analysed. Analysis of the samples was done as per Standards methods (APHA, 1989). The results of the first phase of monitoring are given in Table 5. On the basis of first monitoring results, four zones: Gandhi Park, Atalbundh, Krishna Nagar and Super Market were identified as critical with respect to bacteriological quality of water. Hence, during the second phase of monitoring from September 20 to September 23, 1998 bacteriological analysis of these zones was repeated. The number of sampling locations for second monitoring exercise was 26 and the list is given in Table 6 and results in Table 7.

Table 4 Parameters analysed for water quality monitoring

Parameter
pH
Total dissolved solids
Total hardness
Total alkalinity
Chloride
Sulphate
Total iron
Fluoride
Residual chlorine
Nitrate
Total coliforms

Table 5 First phase monitoring results

	pH	TDS (mg/l)	Chlonde (mg/l)	Sulphate (mg/l)	Iron (mg/l)	Fluonde (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Total Coliform (count/ml)	Res. Chlonne (mg/l)
Water quality standard (MUD)*	7.0-8.5	500	200	200	0.1	1.0	-	200	0	0.2-0.5
Sampling locations										
1. Water treatment plant-Raw water	7	500	115	30	0.01	0.20	160	180	-	-
2. Water treatment plant- Treated water	7	660	304	96	0.05	0.18	136	320	-	2.1
Kila Zone										
3. ESR Inlet	7	820	252	80	0.21	0.22	152	310	-	0.08
4. ESR Outlet	7	880	304	105	1.07	0.20	180	340	-	0.06
5 Household (KZ1)	7	820	310	131	0.09	0.17	208	360	-	0
6. KZ2	7	920	346	108	0.38	0.18	236	360	-	0
7. KZ3	7	820	336	133	0.08	0.17	164	400	20	0.05
8.KZ4	7	680	252	112	0.70	0.19	244	280	40	0
Atalbundh Zone										
9 ESR Inlet	7	800	220	70	1.36	0.23	160	300	-	0.1
10 ESR Outlet	7	880	262	92	0.67	0.23	168	620	-	0
11. AZ1	7.5	1080	672	199	0.13	0.20	284	790	810	0
12. AZ2	7	2100	1013	89	0.82	0.19	188	790	20	0
13. AZ3	7	900	315	90	1.07	0 22	176	460	3360	0
14.AZ4	7	1020	315	95	0.06	0.26	184	300	-	0
15. AZ5	7	1080	289	205	0.23	0.24	160	460	-	0
Heera Das Zone										
16. ESR Inlet	8	2160	855	203	0.19	0.17	364	740	-	0.2
17. ESR Outlet	7	2320	945	206	0.36	0.20	400	660	-	0.1
18 HZ1	7	2180	855	209	0.05	0 15	356	860	-	0
19 HZ2	7	2220	876	199	0.01	0.18	344	640	-	0
20 HZ3	7	2160	887	200	0.02	0.13	348	810	-	0.05
Super Market Zone										
21. ESR Inlet	7.5	660	310	93	0.08	0 21	208	310	-	0.08
22.ESR Outlet	7.5	760	252	92	0 07	0 19	156	330	-	0
23 SZ1	7.5	680	310	92	0 16	0 20	164	570	-	0
24. SZ2	7 5	800	325	110	0 06	0.23	160	360	600	0

	pH	TDS (mg/l)	Chlonde (mg/l)	Sulphate (mg/l)	Iron (mg/l)	Fluoride (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Total Coliform (count/ml)	Res. Chlorine (mg/l)
25 SZ3	8	940	378	124	0 33	0 18	252	340	13000	0
Ranjeet Nagar Zone										
26 ESR Inlet	8	1160	1086	208	0 14	0 15	348	900	-	0.15
27. ESR Outlet	8	2640	971	212	0 28	0 14	336	1110	-	0.1
28. RZ1	8	2960	950	207	0.81	0 13	368	850	-	0
29. RZ2	8	2880	934	209	0 48	0 11	380	920	-	0 06
Krishna Nagar Zone										
30. ESR Inlet	7 5	1220	441	150	0 21	0 15	236	450	-	0
31.ESR Outlet	7 5	1240	541	162	0 42	0.15	264	480	120	0
32.KR1	7 5	2220	535	149	0 23	0 14	384	530	1720	0
33.KR2	7 5	1840	530	169	0 43	0.11	224	610	2200	0
Tube-wells										
34. Heera DasTube-well	7	2340	903	196	0.50	0.18	404	760	-	-
35. Ranjeet Nagar Tueewell	7.5	2480	934	216	0 70	0.21	376	710	-	-
36.CIMMCO Tube-well	7	2360	908	201	0.31	0.17	392	820	50	-
37.RIICO Tube-well	7 5	1840	635	192	1 64	0.19	400	520	-	-
38. STC Housing Board Tube-well	8	1600	651	190	2 08	0.17	412	630	-	-
39. Kila Tube-well	7	1720	598	190	3.54	0.18	384	600	-	-
40.Rajindra Nagar Tube-well	8	1420	724	191	0.40	0.17	376	780	-	-
Gandhi Park Zone										
41. ESR Inlet	7.5	1700	514	175	0.14	0.12	268	700	140	0
42. ESR Outlet	7	1260	346	125	0.19	0.10	212	440	-	0
43 GP1	7	1060	257	107	0.12	0.13	188	650	7100	0
44. GP2	7	1600	462	154	0.36	0.10	208	600	$>10^7$	0
45. GP3	7	840	257	104	0 32	0.11	168	570	6260	0
Rajindra Nagar Zone										
46. ESR Inlet	7	1260	173	9004	0.04	0.17	186	320	-	0.1
47. ESR Outlet	7	940	231	84	0.28	0.17	164	410	-	0.1
48. RN1	7	880	252	85	0.95	0.18	176	480	-	0
49. RN2	7	1020	262	92	0.69	0.17	156	440	-	0.05
Jawahar Nagar Zone										
50. ESR Inlet	7	2380	761	204	0.16	0.13	332	670	-	0.08
51. ESR Outlet	7	4220	887	200	0.11	0.14	340	700	20	0

	pH	TDS (mg/l)	Chlonde (mg/l)	Sulphate (mg/l)	Iron (mg/l)	Fluoride (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Total Coliform (count/ml)	Res. Chlorine (mg/l)
52. JN1	7.5	2680	777	197	0.20	0.11	348	760	-	0
53. JN 2	7	2200	693	203	0.33	0.10	320	690	-	0
54. JN 3	7	2640	735	202	0.15	0.10	336	740	55	0
CIMMCO										
55 CIMMCO CWR Outlet	7	2480	960	203	0.53	0.18	324	730	-	0

Table 6 Sampling locations during second phase of monitoring

Zone	Sampling location	Number of samples
Atalbundh Zone		
	Household	5
Super Market Zone		
	Household	3
Krishna Nagar Zone		
	Household	2
Gandhi Park Zone		
	Household	3
STC Housing Board Zone		
	ESR Outlet	1
	Household	2
Hospital Zone		
	ESR Inlet	1
	ESR Outlet	1
	Household	1
Tube wells		
	Baraf Wala Kuan	1
	Janana Hospital	1
	Panchayati temple	1
	Jahgina gate	1
	Ketan gate	1
	Atalbundh PHED Office	1
	Mehant Wala Kuan	1

Table 7 Second phase monitoring results

	pH	TDS (mg/l)	Chlonde (mg/l)	Sulphate (m g/l)	Iron (mg/l)	Fluonde (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Total coliform (count/ml)	Res. Chlonne (mg/l)	Nitrate (mg/l)
Water quality standard (MUD)	7.0-8.5	500	200	200	0.1	1.0	-	200	0	0.2-0.5	45
Sampling locations											
Gandhi Park											
1. GP1	7	-	-	-	-	-	-	-	Nil	0	4.8
2 GP2	7	-	-	-	-	-	-	-	Nil	0	6.2
3. GP3	7.5	-	-	-	-	-	-	-	4000	0	6.6
Super Market Zone											
4. SM1	8	-	-	-	-	-	-	-	Nil	0.12	3.5
5. SM2	7.5	-	-	-	-	-	-	-	40	0	4.8
6. SM3	8	-	-	-	-	-	-	-	Nil	0	4.4
Krishna Nagar Zone											
7 KN1	7	-	-	-	-	-	-	-	Nil	0.1	4.6
8. KN2	7 5	-	-	-	-	-	-	-	Nil	0	3.4
Atalbundh Zone											
9 AZ1	7	-	-	-	-	-	-	-	460	0	6.2
10 AZ2	7	-	-	-	-	-	-	-	Nil	0.08	5.7
11 AZ3	7	-	-	-	-	-	-	-	Nil	0	4.8
12 AZ4	7 5	-	-	-	-	-	-	-	Nil	0	4.0
13 AZ5	7	-	-	-	-	-	-	-	120	0	5.3

	pH	TDS (mg/l)	Chlonde (mg/l)	Sulphate (m g/l)	Iron (mg/l)	Fluonde (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Total coliform (count/ml)	Res. Chlorine (mg/l)	Nitrate (mg/l)
STC Housing Board											
14 ESR Outlet	7	1650	707	187	0 11	0 08	410	623	Nil	0	4.8
15 STC1	7	1630	712	189	0 13	0 09	360	611	1.4×10^{4}	0	4.8
16 STC2	7	1660	733	182	0 10	0 11	400	636	Nil	0	4.4
Hospital Zone											
17 ESR Inlet	7	1170	661	172	0 14	0 11	320	344	Nil	0	2.6
18 ESR Outlet	7	1140	579	171	0 13	0.10	300	378	$>10^{7}$	0	3.1
19. HZ1	7	1120	565	177	0 11	0.09	290	362	Nil	0	2.9
Tube-wells											
20. Baraf wala kuan	7.5	1340	1321	208	0 07	0 11	620	731	1290	-	84.4
21. Janana hospital tube-well	8	1250	1045	207	0 13	0 10	450	655	Nil	-	88.8
22. Panchayati temple (Gopalgarh)	8	1290	973	204	0 09	0.08	500	630	$>10^{7}$	-	73.5
23. Jahgina gate tube-well	8	1180	1025	170	0 12	0 08	340	764	Nil	-	5.3
24.Ketan gate boring	8	840	980	210	0 11	0 10	445	692	Nil	-	23.4
25. Atalbundh PHED office well	8	1090	666	137	0 14	0.12	720	420	$>10^{7}$	-	11.9
26. Mehant wala kuan	7.5	1240	861	200	0.06	0 09	630	546	-	-	102.5

Analysis of sampling results

- The groundwater quality of Bharatpur is appreciably high in TDS (Total dissolved solids) and chloride content, corroborating the saline nature of the water. The Chloride concentration exceeds 900 mg/l and TDS concentration exceeds 2000 mg/l in tube-wells at Heera Das, Ranjeet Nagar and CIMMCO. The Chloride and TDS profiles of each zone storage reservoir outlet and of the tube-wells in Bharatpur are given in Figure 1 and Figure 2, respectively. The average zonewise TDS profile is shown in Map 2. In Kila, Rajindra Nagar, Krishna Nagar and Super market, the concentration of TDS and chlorides is lower than the other zones. The quality of water in Super Market is the same as of treated water since there is absolutely no blending. This is on account of blending the treated water from Malah water works with groundwater.

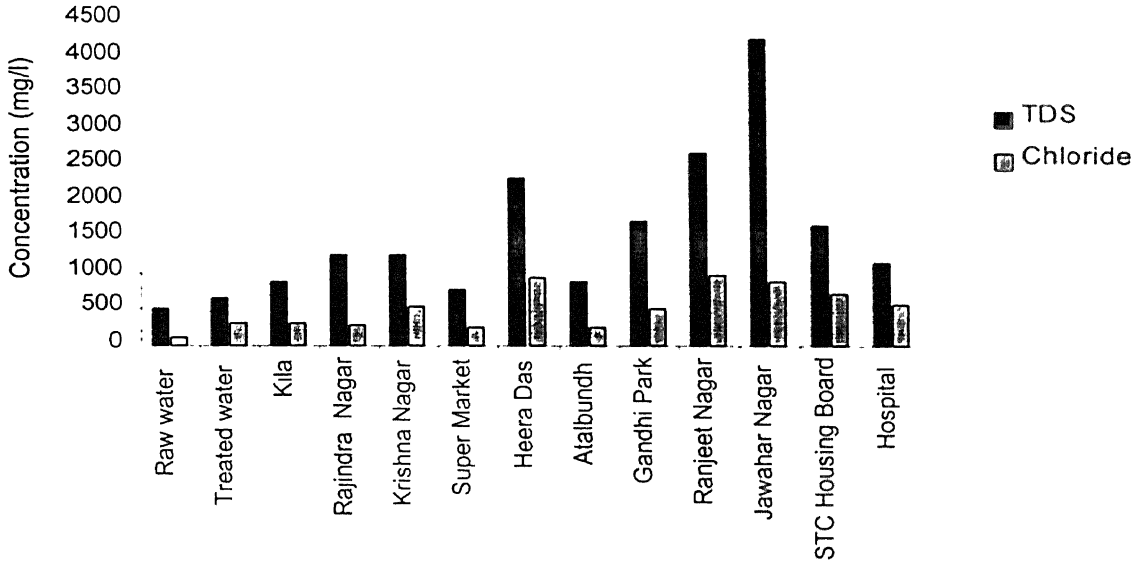
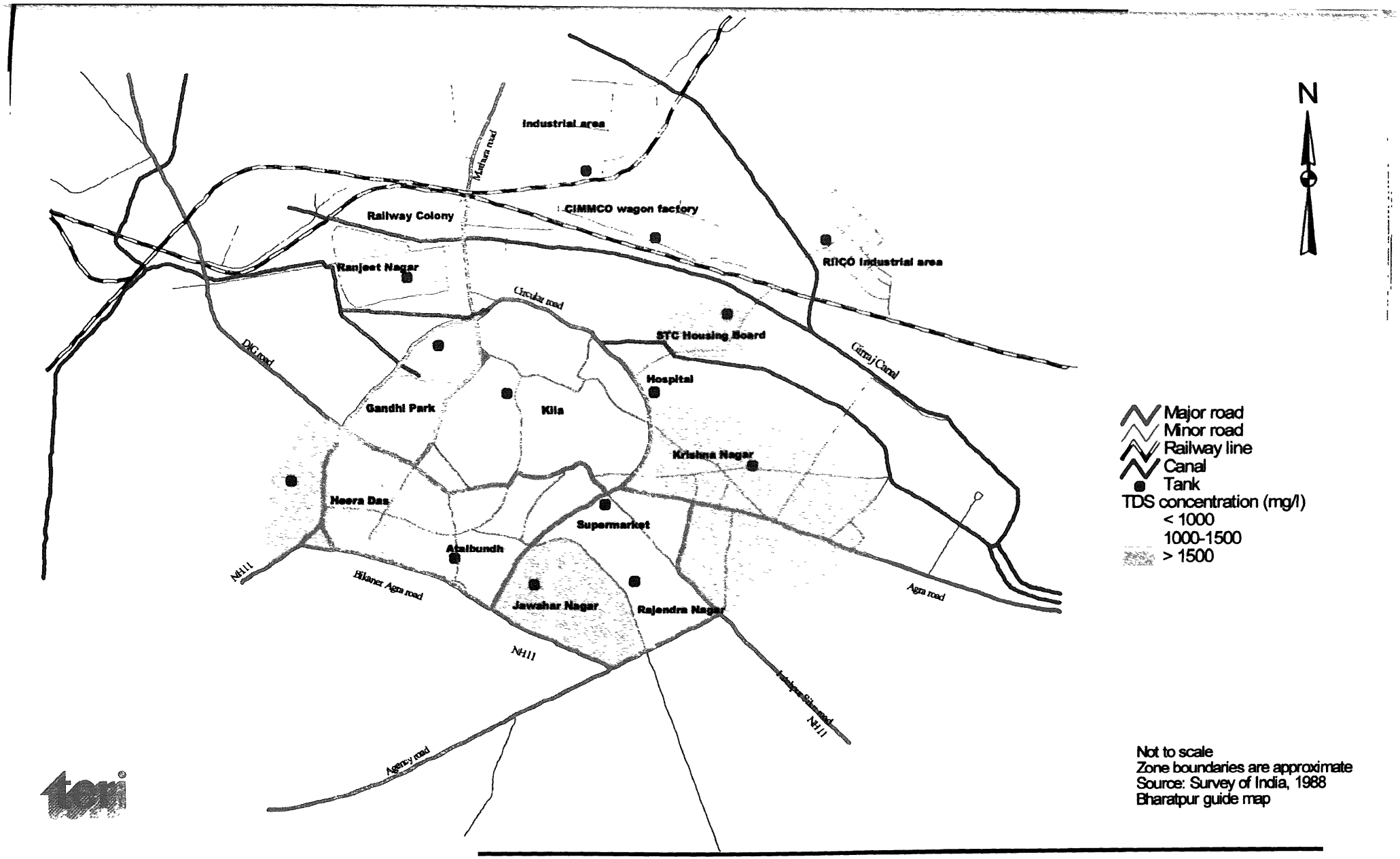


Figure 1 TDS and Chloride concentration profile of each zone storage reservoir outlet



Map 2 Zonewise average TDS concentration profile in Bharatpur

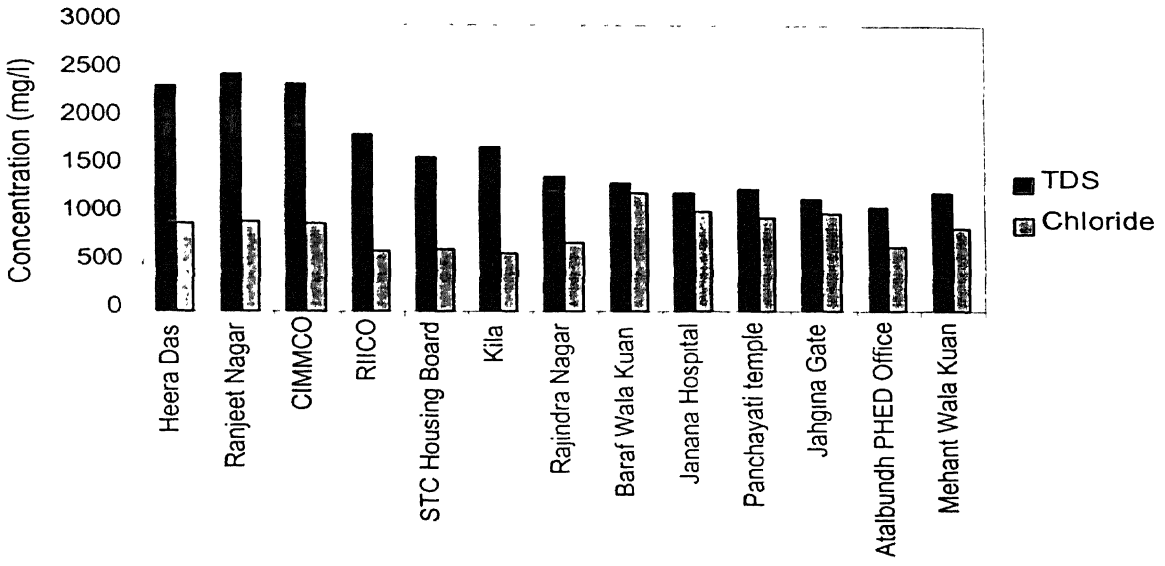


Figure 2 TDS and chloride concentration profile of tubewells

Residual chlorine concentration in the distribution system is almost negligible. A total of 71% of the samples tested for residual chlorine showed nil concentrations. Residual chlorine profile of each zone storage reservoir outlet is shown in Figure 3. Post-chloroination process at Malah water treatment plant does not provide a sufficient contact time of atleast 30 minutes. The supply of bleaching powder to each zone is erratic and inadequate. In case bleaching powder is available, the operators of each zone storage reservoir dump the bleaching powder into the storage reservoir directly without any proper mixing.

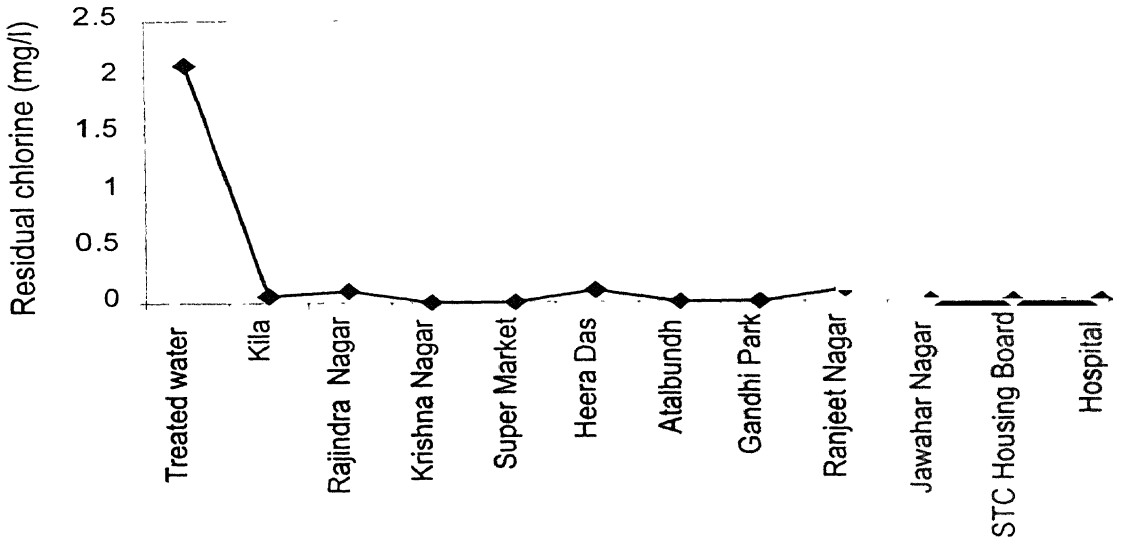
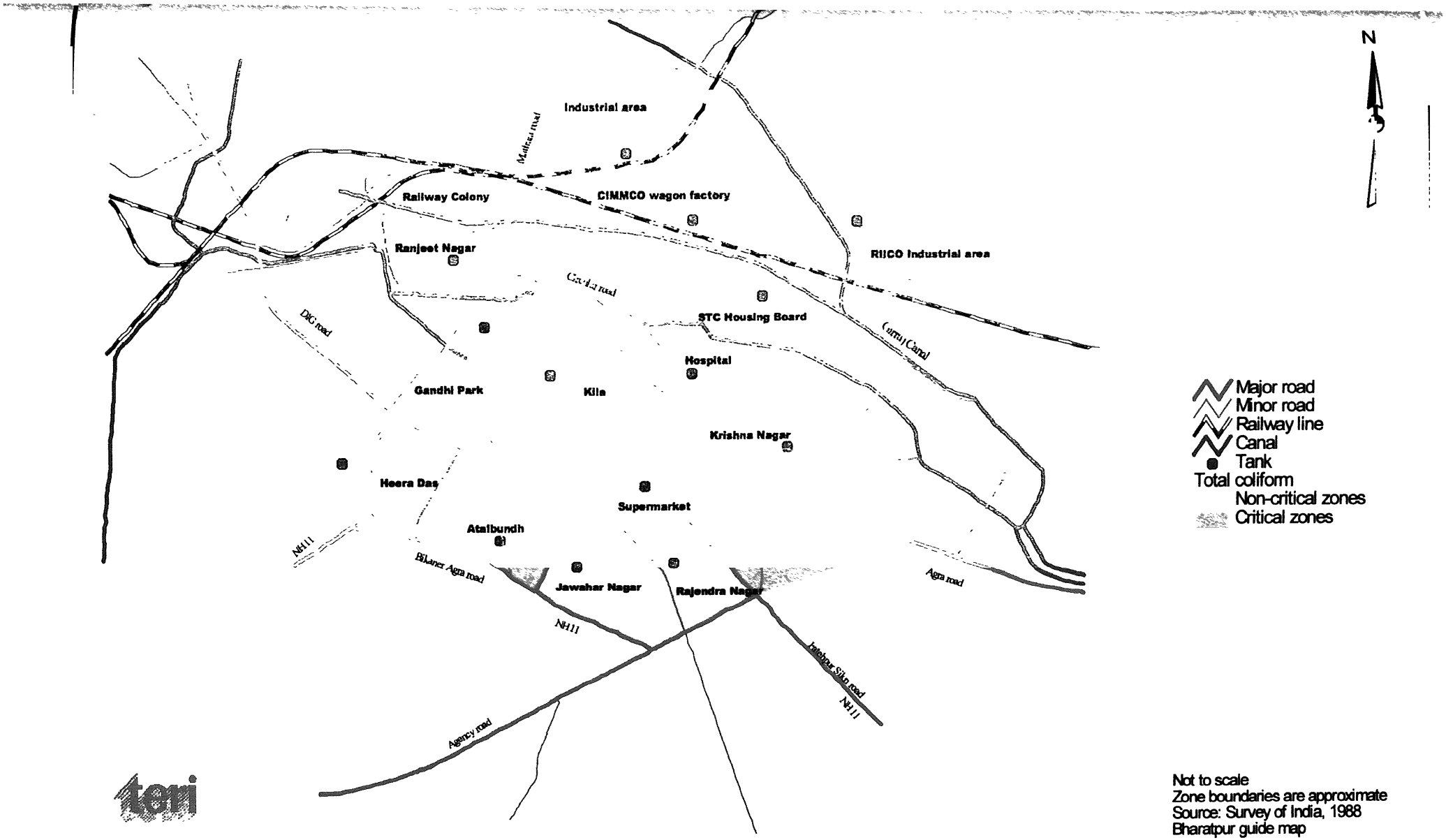


Figure 3 Residual chlorine profile of each zone storage reservoir outlet

- Bacteriological quality of water in Gandhi Park, Krishna Nagar, Super Market and Atalbundh is critical as shown in Map 3. Total coliform count of 33% of the samples analysed exceeded the Ministry of Urban Development standard of 0 coliforms/ml. The majority of the contaminated samples were from households, indicating possible cross-connections with drainage system.
- Iron concentrations are high in Bharatpur, exceeding the MUD standard of 0.1 mg/l. Corrosion of old water supply pipelines is perhaps adding to the iron content of the drinking water. Tube-wells at RIICO, STC Housing Board, and Kila show iron concentrations ranging between 1.6 and3.5 mg/l.
- Shallow wells dug by PHED in Bharatpur show high nitrate concentrations exceeding the MUD standard of 45 mg/l. Some of these wells namely Janana Hospital (Refer Figure A.2 in Annexure II), Panchayati Temple are situated very close to Sujan Ganga. Mehant Wala Kuan in Atalbundh (Refer Figure C.2 in Annexure II) showed nitrate concentration of 102.5 mg/l because of possible leaching of contaminated water into the well. However, all wells showing high nitrate concentrations did not test positive for coliforms indicating that possible contamination with drainage water is not the primary factor. A detailed analysis of the aquifers for each tube-well will reveal the cause of contamination.
- Fluoride and sulphate levels in Bharatpur are well within the standards.

The water quality in Bharatpur undergoes critical transformations on account



Map 3 Bacteriological quality of drinking water in Bharatpur: critical zones

of mixing of water from different sources. The treated surface water (source: Bund Baretha) complies with water quality standards but when it is mixed with groundwater, the quality deteriorates beyond acceptable standards. Hence, it is very essential for PHED to augment the supply from Bund Baretha as early as possible to limit the usage of groundwater to a minimum.

3 Community perceptions on drinking water

Community denizens assess and perceive drinking water quality on the basis of aesthetic characteristics i.e. taste, colour, odour. Drinking water may meet the aesthetic requirements but may fail to meet the bacteriological/chemical standards. Thus, the guiding approach to understand consumer needs and problems is to enhance community participation in planning and decision making process. Public awareness &education programmes, primary social surveys, health &hygiene education programmes are some of the tools employed by policymakers to initiate community involvement and determine consumer's insights. As a secondary objective of this study, a community survey in Bharatpur was conducted to determine the perceptions on drinking water quality and status of water supply in the town.

The community survey was conducted on the basis of a questionnaire (Refer Annex I) which was designed to extract and analyse the following information from the people.

- Source of drinking water
- Water supply quantity
- Aesthetic problems associated with drinking water quality
- Type of storage facilities at households
- Health problems related to contaminated drinking water
- Steps taken by households to improve water quality

The survey was held in 10 zones covering 49 households. The target group during the survey were primarily women because women are mainly responsible for water storage and maintenance of hygiene and clean environment in the households. The primary observation during the survey was that apart from appalling socio-economic conditions, scarcity of potable water has further deteriorated the standard of living. Water being a basic necessity of life, is essential to maintain a healthy and nourished body. Bharatpur citizens on contrary to law of the survival of the fittest have accustomed themselves to the problem even if it demands resorting to sewage ponds for water, thereby associating high risks to their health. The local authorities resemble a picture of indifference and lackadaisical behaviour. The confidence of masses in the governing mechanism to tackle day-to-day problems is exhausted. Initiatives to build an understanding and transparent relationship between the two groups are missing. The onus of accountability of the present problems lies both on the government and people. Pressure of increasing population forced authorities to

take steps in ephemeral time without proper planning &analysis. Citizens on other hand got attracted to short term gains and did not perceive the resulting future scenarios.

The inferences from the community survey can be summarised as follows:

- Primary source of drinking water in Bharatpur is water supplied by PHED which is either treated surface water blended with groundwater or purely groundwater. In event of no or low supply people depend on water from private tube-wells or tankers. The availability of water is critical in Gandhi Park, Atalbundh, Kila and Super Market zones. The morning supply is almost consistent in all zones for 30 minutes and evening supply is intermittent and extends for 15-20 minutes only. A typical community queue for filling water during morning water supply is shown in Figure C.1 (Refer Annexure II).
- Quantity of water supplied ranges from 25-40 lpcd equivalent to 3-4 buckets in a household. The availability of water is considerably affected in certain households because of the use of suction motors and manual suction devices called "khenchoos". Khenchoos are more popular among the poor people and are indispensable in certain colonies. In an attempt to restrict the use of suction motors by affluent people, PHED requests Bharatpur electricity department to shut off electricity during water supply timings. But the use of Khenchoos continues to be a problem of people living at tail end of each zone.
- Water tap connections for most of the households are located near the roadside kerbs. Water connections exist at plinth level since water pressure is insufficient to rise till ground level. As a result, water pipelines pass directly through or overlay a short distance above the side drains. Water connections of such kind are given in Figure B.1 and B.2, (Refer Annexure II) respectively.
- Quality of drinking water is of secondary concern to the masses. Fulfillment of daily requirement for water consumption assumes prime importance in each household. This was evident from the lack of awareness among people on water quality. Very few households during the survey used boiling or alum or some kind of filter to reduce the risks of drinking contaminated water. Community perceptions on drinking water quality were restricted to colour, taste and odour. Almost all households during the survey complained of receiving "muddy or black" water with bad smells.
- The level of basic health and hygiene education among the people is very poor. Importance for segregation of drainage and water supply lines does not exist. The water supply line of nearly every household passes through the roadside drain. Initiatives by the people themselves instead of waiting for authorities to do something should have led to covering of these drains to avoid breeding of disease causing vectors. Unfortunately, this has not occurred in Bharatpur. People are continuously being affected by water borne

and vector diseases. According to health department estimate around 9000 people have been affected from April this year so far by gastro-enteritis, jaundice, Hepatitis b, diarrhoea etc.

It is difficult to overturn the present situation in Bharatpur by packaging a ready made solution. There is an urgent need to increase the level of effort by the government and by the people. People have to act as agents of change to carry forward the momentum. The community in its initial efforts should conduct an internal assessment of the needs and problems at the basic grassroot level. The same should be represented to local/regional public representatives for necessary action and implementation.

4 Water quality surveillance in Bharatpur

Water quality surveillance mechanisms aim to reduce the risks of contaminated water to human health by way of a systematic and continuous monitoring of drinking water systems. The extent of surveillance program is greatly influenced by the technical and economic strength of the local municipalities. The level of awareness and participation offered by the community is such programs determine its success or failure. Surveillance programs in developing countries often overlook the importance of coordination with health professionals. Thus, the inter-flow of information on water quality and health statistics is not transparent and remains uncorrelated.

The formulation of a water quality surveillance program for Bharatpur will involve setting up a common taskforce group comprising of professionals from municipalities, water supply & health department and community representatives. The Strategic Sanitation group (SSG) formed under the aegis of the World Bank is a perfect example except that currently it is devoid of public representatives. It is imperative to include this sub-group in order to do a partial role transfer of the current monitoring system to the community. This will ensure that public at large will act as a watchdog in its neighbourhood and reports systems default to the SSG for necessary action. It is further proposed to setup community zonal groups in each water supply zone of Bharatpur. Each group will comprise of one primary zonal representative and three-four secondary associates. Zonal representative will form the core members of public sub-group in the SSG. The zonal group would be assigned the following responsibilities:

- Identification of problem areas in each zone and formulation of possible remedial measures and follow up of implementation activities with SSG
- Increased level of activities in community education and involvement in water quality, sanitation, health and hygiene issues by virtue of micro-level primary surveys, mass communication tools etc.
- Monitoring of basic drinking water quality parameters on a regular basis and reporting of results to SSG. SSG will direct PHED to report its water quality results as well. An assessment of both sets of results will ensure proper accountability on behalf of PHED. The zonal group will responsible for doing pH, residual chlorine, total dissolved solids, nitrates and total coliforms. It is recommended that residual chlorine be done on a weekly basis and other parameters on a monthly basis. Assuming the current population of Bharatpur as two lakhs, the number of samples at household level to be

analysed by the zonal groups is outlined in Table 8.

Table 8 No. Of samples in each zone to be analysed by zonal groups

Zone	No. of samples at households
Kila	4
Super market	3
Atalbundh	5
Gandhi Park	3
Ranjeet Nagar	3
STC Housing Board	2
Krishna Nagar	2
Rajindra Nagar	2
Jawahar Nagar	3
Heera Das	3

- Monitoring the application of bleaching powder in each zone. This would involve assessment of bleaching powder requirements in each zone, the necessary equipment and apparatus for its proper mixing and determination of the exact dosage in each zone.

The selection of the zonal groups with appropriate competent members is critical for establishing the creditability of the proposed community surveillance scheme. The availability of sufficient resources is also a limiting factor to maintain a continuous level of interest in the groups. Public representatives on their behalf on a voluntary basis would have to devote considerable time and energy in order to ensure the smooth functioning of surveillance activities.

The PHED as the main executing agency of the surveillance system would have to refocus its strategies to establish synergies with the zonal representatives. The current water quality monitoring needs to be streamlined effectively. The existing PHED laboratory is not well equipped, technically as well resource wise to handle the monitoring of the distribution network. There is a significant time delay in reporting of the results and follow up action. It is recommended that PHED should immediately initiate water quality monitoring as outlined below:

- Distribution system of Gandhi Park, Atalbundh, Super Market and Krishna Nagar should be analysed very critically for bacterial contamination. The dosage of residual chlorine in these zones should maintained at 0.5 mg/l.
- Water quality monitoring in all zones should be carried out as per WHO guidelines given in Chapter 1. Sampling frequency for bacteriological analysis i.e. *E.coli* or fecal coliforms should be maintained strictly as per guidelines. The water quality analysis should be reported monthly to the SSG.
- Detailed assessment of water quality of all PHED operated tubewells in Bharatpur city especially for nitrate and toxic parameters like lead, chromium, arsenic. Specific correlation's between coliform presence and

nitrate concentrations should be ascertained to confirm the possibility of contamination of ground water with sewage or drainage. This is especially essential for all tubewells close to the Sujan Ganga.

- Residual chlorine levels are low in Bharatpur on account of non-availability of bleaching powder on a regular basis. The required bleaching powder stocks should be estimated well in advance, preferably a month earlier in order to procure it from the designated vendors.
- Water supply from Bund Baretha should be restored to the original capacity of 10.4 MLD as early as possible. The current shortfall on account of number of leakages in RCC gravity main is affecting the water quality. Blending of treated water with ground water in appropriate ratio will help lower the high TDS and chloride concentration.

The SSG should act as a governing body to coordinate the activities and ensure the flow of information between the sub-groups. The community zonal groups need to closely interact with the local NGOs to harness the available resources and cooridnate community awareness programmes jointly. The PHED on the other hand should establish a feedback mechanism with the municipal corporation to correlate water quality and public health. The flow chart highlighting the recommended organizational structure for water quality surveillance in Bharatpur is given in Annexure III. It is hoped that a steady build up of water quality surveillance programmes in Bharatpur will deliver better quality and adequate quantity of water and help reduce the incidences of waterborne diseases.

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Annexure I

Community survey questionnaire
on
Perceptions of Drinking Water Quality in Bharatpur

Conducted by :
Tata Energy Research Institute (TERI)
New Delhi

ESR Zone/Area :	Name of respondent : No of family members :
Drinking water sources: Water sources for other uses (Bathing/Washing)	*Piped* : (Yes)/(No) *Non-piped* : (Private tubewell), (Handpump), (Open dug well), (Tanker), Any other ( ) Piped/Non-piped

Quantity and timings of water supply:	Morning	Evening
	Summer(Apr-June) Major source : Piped/Other	
	Monsoon(July-Sept) Major source : Piped/Other	
	Post monsoon(Oct-Nov) Major source : Piped/Other	
	Winter(Dec-Mar) Major source : Piped/Other	

Problems with drinking water quality *Aesthetics* *Odor* *Any other* Does the household have water reservoir/storage tank	 Coloured/Highly turbid Yes/No Salinity/Any other Yes/No
Capacity of reservoir	
Placement of reservoir	Overhead/Underground/Any other
Material of which reservoir is built	Plastic(Sintex)/Concrete/Any other
Frequency of cleaning the reservoir	Yearly/Half-yearly/Any other
Health problems related to contaminated drinking water	Type of diseases : Frequency/seasonal :
Steps, if any taken by the household to improve water *quality* Any other problems Comments & suggestions	Boiling/Use of filters (Aquaguard)/Chlorine tablets/Any other

Annexure II

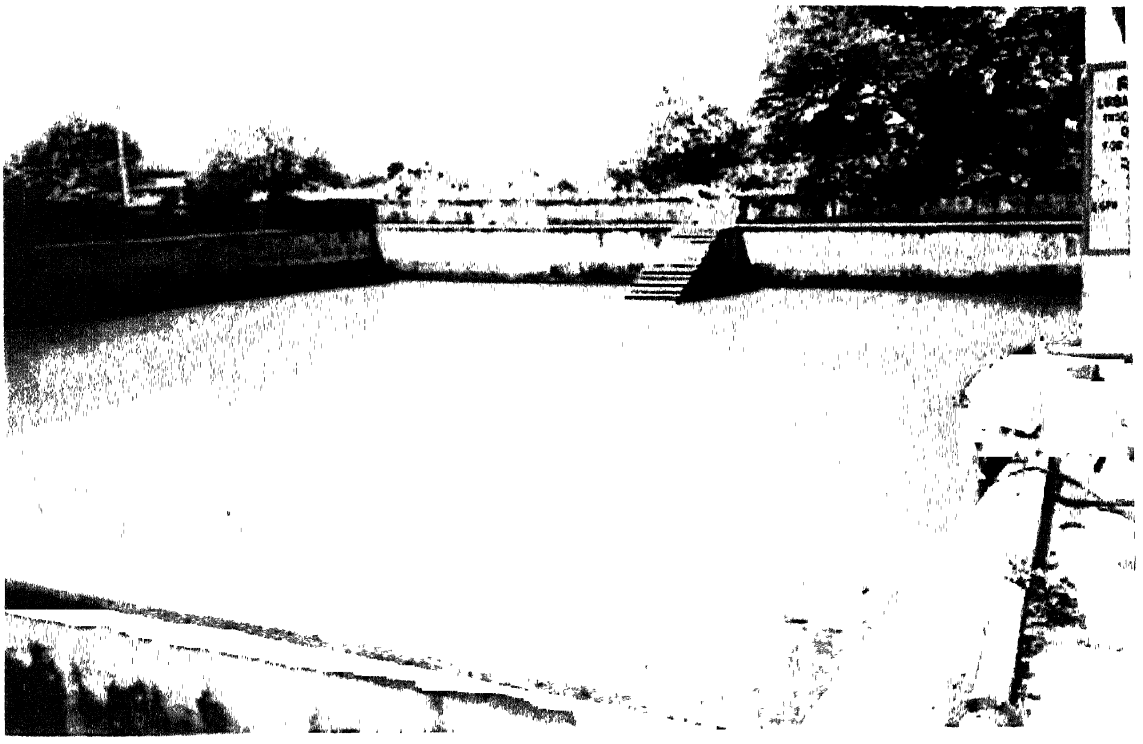

Figure A.1 Raw water sedimentation tank

Figure A.2 Tubewell near Janana hospital and Sujan Ganga

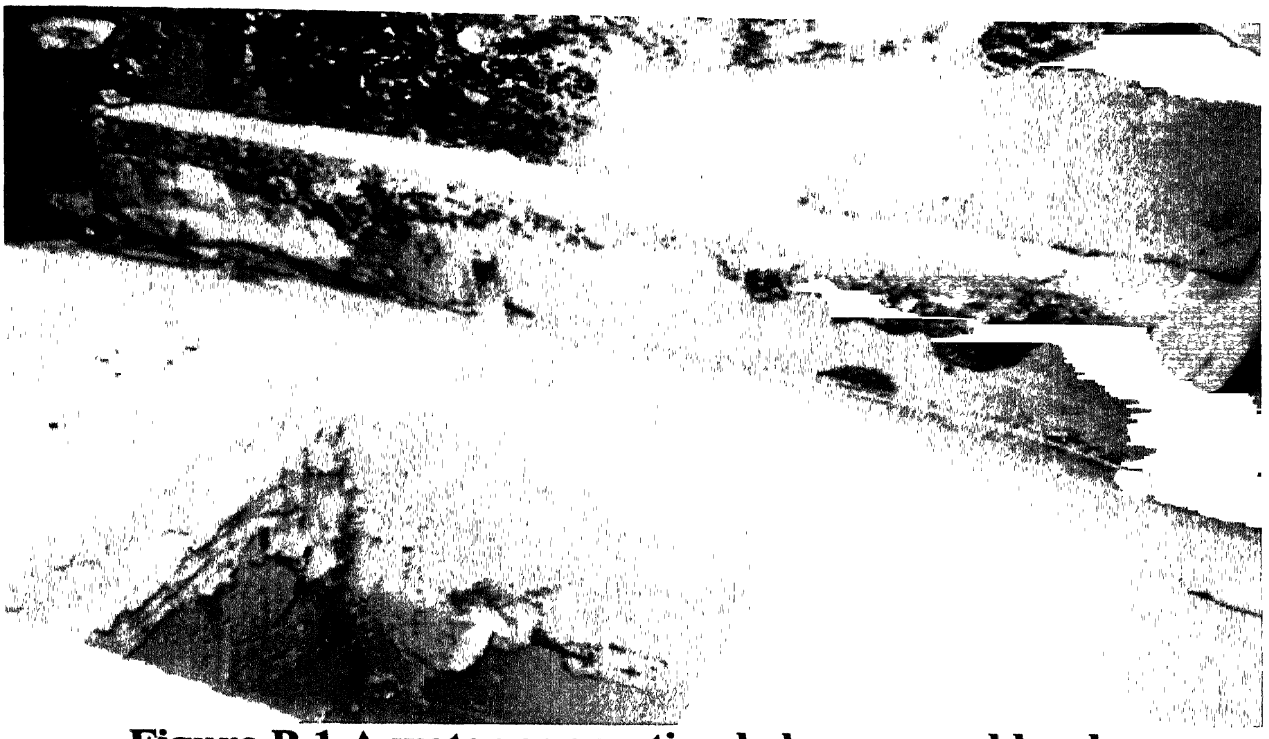

Figure B.1 A water connection below ground level

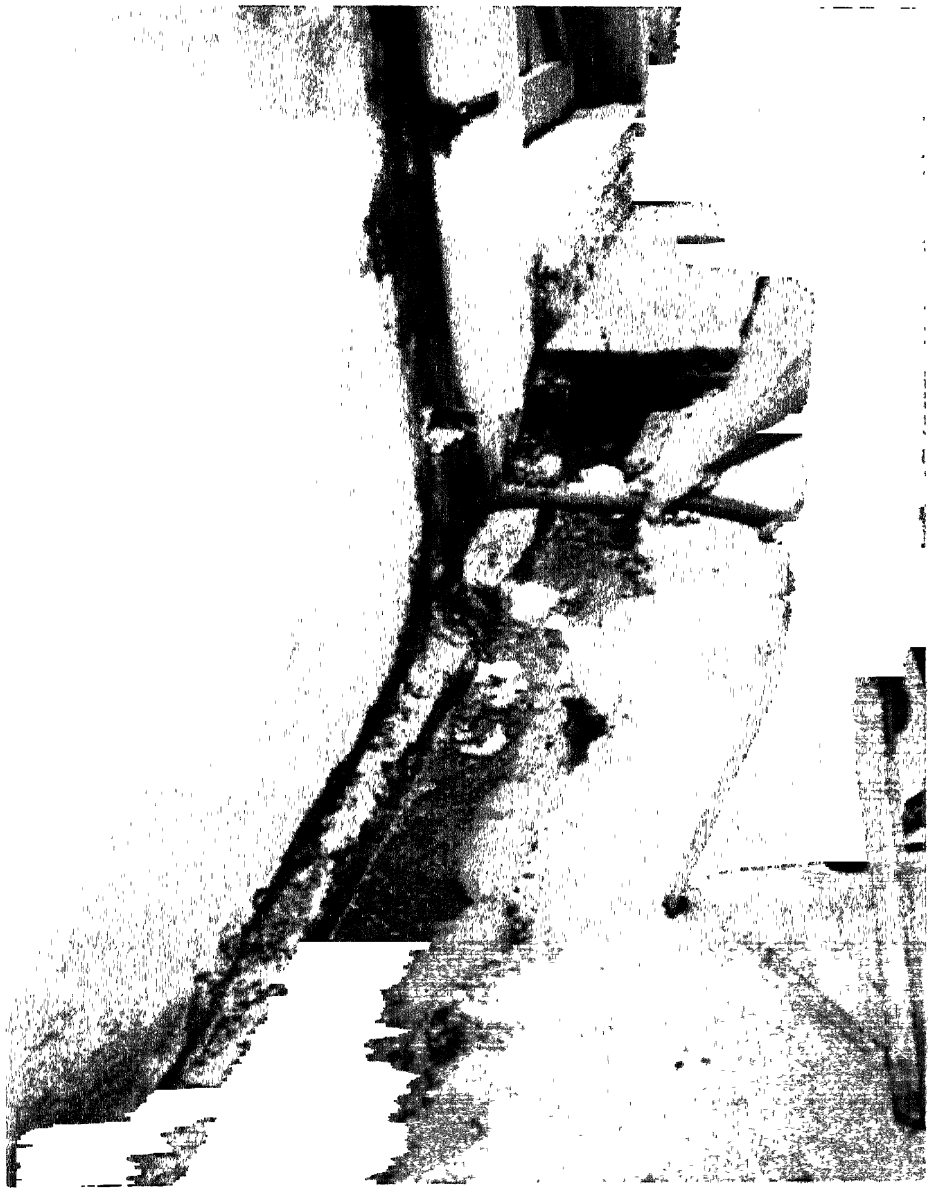

Figure B.2 A water connection close to side drain

Figure C.1 Community queuing up during morning water supply

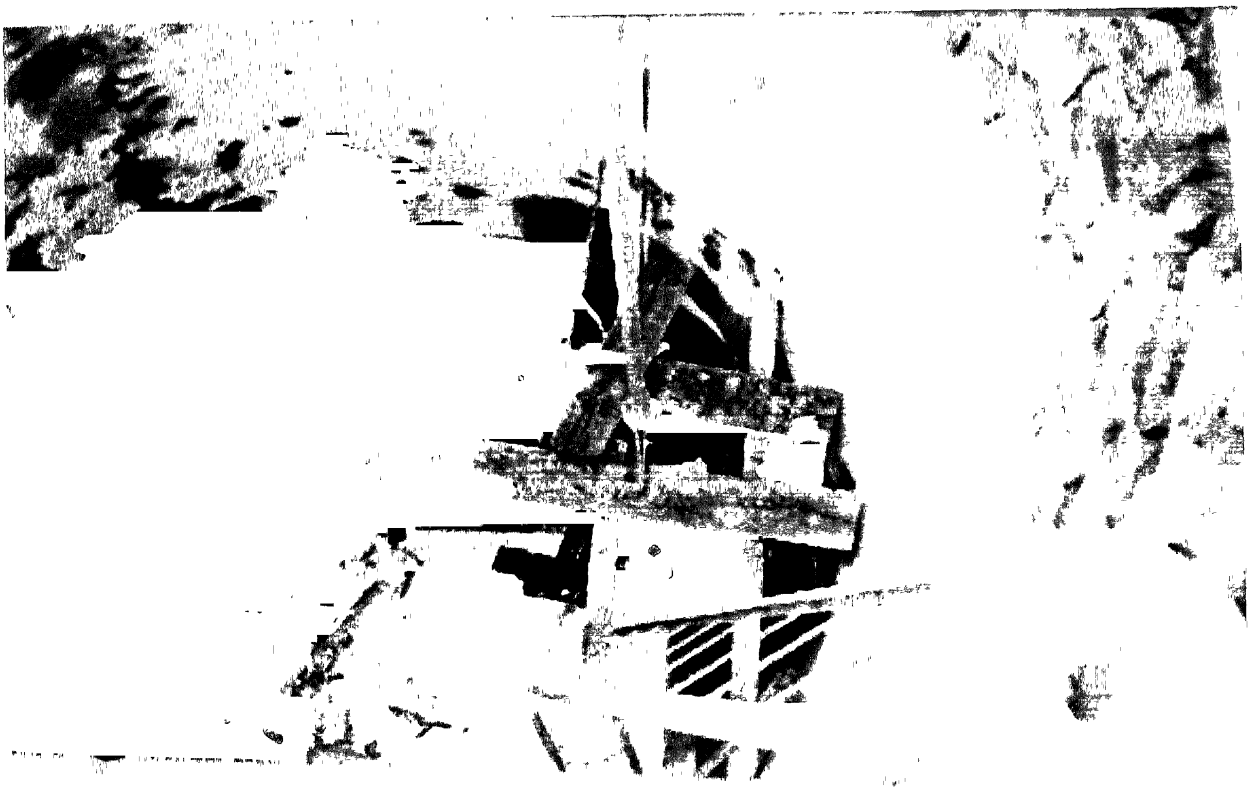

Figure C.2 Mehant wala kuan in Atal Bandh

Annexure III

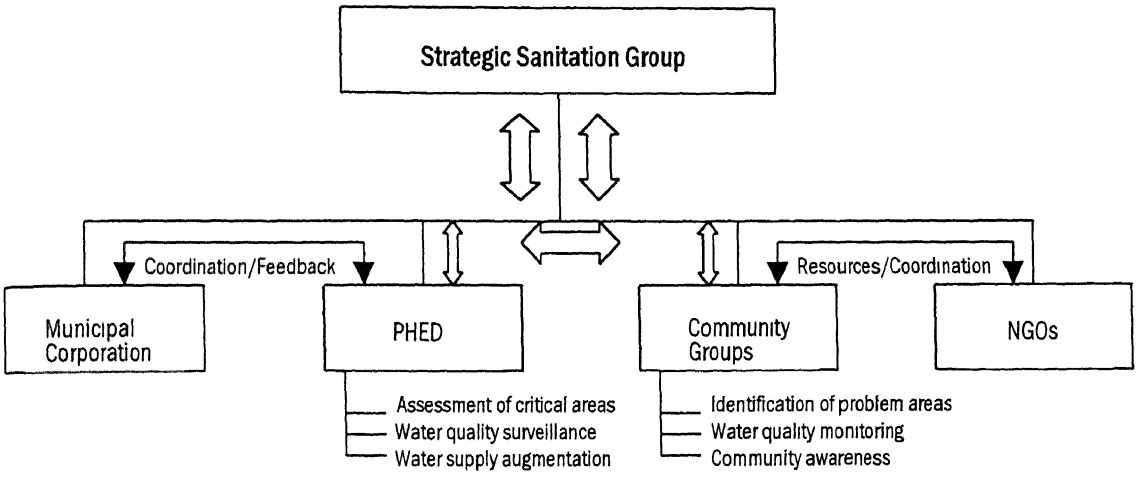

Figure 4: Organizational structure for water quality surveillance in Bharatpur